AD NUMBER
AD383117
CLASSIFICATION CHANGES
TO confidential
FROM secret
AUTHORITY
31 Jul 1979, per document marking, DoDD 5200.10

AD- 383117

SECURITY REMARKING REQUIREMENTS

DOD 5200.1-R, DEC 78

REVIEW ON 06 JUL 87

SECURITY
MARKING

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NRL Memorandum Report 1787
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A Digital Storage Wide Dynamic Range Signal Processor

[Unclassified Title]

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ABSTRACT
(Secret)

The Naval Research Laboratory is in the process of obtaining a new 60-db Dynamic Range Digital Processor for use with its over-the-horizon radar. It consists of the following subunits: (1) input control and general process controller, (2) digital core memory, (3) analog scanning filters and (4) dual display unit. It will operate at nominal PRF's of 180, 120, 90, 60, 45, 22-1/2 and 11-1/4 pulses per second with storage times of 10, 5, 2.5, 1.25 and 0.625 seconds in the doppler range mode and 110, 160, 220, 330, 440 and 880 seconds in the doppler time mode. An analog tape unit and a 12-bit digital tape unit which records up to four receiver channels are available at all times. These records can be analyzed with complete flexibility of analyzing parameters at a later time. The operational control of the processor is inserted in the process controller in the form of a magnetic or punch paper tape program and the general operational concept can be varied within wide limits by writing new programs. The day-to-day radar parameters and corresponding processor parameters are entered by use of typewriter control at the display unit. The displays will present data in both doppler-range and doppler-time formats and in addition will give amplitude versus range or time at manually selected doppler frequencies. A coherent video target simulator of high quality is included to provide a processor check and to aid in evaluation.

PROBLEM STATUS

This is an interim report on one phase of the problem; work is continuing on this and other phases.

AUTHORIZATION

USAF MIPR (30-602) 64-3412
dated 26 March 1964
and
ARPA Order No. 160, Amendment #7
dated 13 September 1965
to the Naval Research Laboratory
NRL Problem 53R02-42

A DIGITAL STORAGE WIDE DYNAMIC RANGE SIGNAL PROCESSOR

I. INTRODUCTION

Since 1958 the Naval Research Laboratory has been using an analog drum storage signal processor as part of its MADRE radar. When Project MADRE was completed and this Laboratory's effort was expanded into a more general over-the-horizon radar the same processor was used. The original drum was replaced with a second generation drum making use of improvements in the state of the art, but the general features of the processing remained the same. The data presented by the Naval Research Laboratory at previous ARPA OTH meetings and in NRL reports were for the most part analyzed by this processor. The processor suffered from two major limitations. It had a dynamic range limited to not more than 30 db and probably a better practical limit was 26 db. It also lacked flexibility. It was essentially a 180-PRF system but by indirect methods it was made to operate at several lower pulse recurrence rates. The storage time was fixed, as was the output bandwidth. Specifications were drawn up for a new processor to eliminate the limitations and for the past one and one-half years the 60-db processor has been under development by the Heavy Military Electronics Department of the General Electric Company under contract Nonr 4903(00)X. The funding was provided by the Advanced Research Projects Agency and the United States Air Force. It will be delivered in June of 1967 and when fully integrated into the system it is expected to be a very valuable and flexible tool for further OTH research.

II. EQUIPMENT DESCRIPTION

The afore-mentioned limitations have been overcome in the new equipment by the use of a digital core memory as the storage and time-compression medium, a small general-purpose computer as the processor controller and data conditioner, and high-dynamic-range analog analysis circuitry. The processor uses solid state circuits throughout, with the exception of the display cathode ray tubes. Photographs of the equipment are shown in Figs. 1, 2 and 3. A summary of the signal processor specifications is given in Tables 1 and 2.

The 60-db Dynamic Range Signal Processor performs a real time scanning filter doppler analysis of selected time-compressed coherent video data from the NRL-OTH radar receivers. It does this over a 60-db (minimum) linear dynamic range at one of several PRF's and input sample rates and in one of several operating modes. These parameters are selected through a general-purpose computer whose use as the signal processor controller permits flexible operation and provides for simple and inexpensive growth as new operating modes are incorporated.

The operation of the 60-db processor is described in terms of the block diagram, Fig. 4. The main functional blocks of the system are seen to be the system timing function, the analog-to-digital converter, the computer, two mass memories, two digital-to-analog converters, two coherent doppler analysis channels, and the displays.

The system timing portion of the processor provides timing signals related to the radar PRF and the signal processor sample timing for the entire radar. as well as for the signal processor. In the tape-playback mode it generates pseudo-radar timing to enable processing to be carried on at real-time rates and with real-time parameters.

The signal processor can accept coherent video from up to four receiver data channels, a backscatter (non-clutter-filtered) channel, along with a voice channel. The selected channels are sequentially gated, time-multiplexed and each channel converted to a 12-bit digital number. The A/D outputs are passed into the control computer through a high speed "Direct Data Channel."

The computer, a DDP-116 with 16K memory, is the heart of the signal processor in that it performs the major functions of input buffering, tape recording, and reformatting and output buffering of data, as well as several other real-time and nonreal-time functions associated with the signal processor. Real-time data from the A/D converter are stored (buffered) in a section of computer memory until a sufficient number of samples have been accumulated to write a record on magnetic tape. At this time the buffered samples are recorded and a selected portion is transferred to an output buffer (in the computer). At the time of transfer a reformatting of data takes place so that the samples will be stored in the mass memories in a "range bin format." That is, data which enter the computer as sequential range samples for each pulse repetition period in order, are stored as short-time histories of data from several pulse repetition periods. As soon as an output buffer has been filled these data are loaded into the mass memories for readout, D-to-A conversion, and analysis. In the nonreal-time, tape-playback mode a similar buffering and reformatting takes place. In this mode, of course, the source of input data is the magnetic tape recorders.

The two mass memories are identical (2 μsec cycle, 8K by 60 bits each) and can be set up independently as far as memory, analysis, and display parameters are concerned. The function of the memories is to store enough time history of each range bin of data to allow coherent spectral analysis to the desired doppler resolution, and to provide sufficient time compression (the ratio of memory readout rate to PRF) to permit a complete doppler analysis by the scanning filter analyzer, in less than one-half the storage time.

Each mass memory output, which consists of 12-bit digital data samples, is presented to a digital-to-analog converter at a rate up to a 2.5 mHz, providing a time compression factor of approximately 14,000 to 1. Each converter, which is capable of conversion of 10-bit words at rates up to 5 mHz, provides an analog output to one channel of the coherent doppler analysis equipment. An analysis channel performs essentially a conventional scanning filter spectral analysis using high-dynamic-range analog circuit techniques. The flexibility afforded by the computer-controller is utilized by permitting computer selection of analysis predetection filter bandwidth ("doppler resolution"), time-weighting function, and output postdetection (low-pass) video filters. A Hewlett Packard Frequency Synthesizer is employed as the analyzer scanning oscillator, with its frequency under complete and direct control of the computer. The analysis channel can be operated in either a logarithmic mode over the entire 60-db dynamic range, or in a linear mode over a selected 40-db portion of the range.

The analysis channel outputs are sent to the display console for presentation to the operator on a high resolution CRT display. These displays present the information in a doppler versus range, doppler versus time, or amplitude versus range-or-time format depending on the particular mass memory storage mode and analysis mode selected. Also provided is a display of amplitude versus frequency at a selected range or time (spectrum display), as well as a means of generating a post-analysis, noncoherent doppler versus time display.

Except for a few display and analysis controls at the display console, such as doppler and range/time strobe controls, all parameters, commands, modes, etc., are controlled directly through the computer by operator inputs at the ASR-35 teletypewriter. Parameter inputs do not immediately cause a change in operating mode, but are placed in a "stand-by table" in the computer memory. Thus a new or partially new list of parameters can be prepared while the processor continues to operate in the previously selected mode. A verification program within the computer provides a check for the operator on whether he has selected a complete and permissible set of operating parameters. The operator may give a command to introduce a new set of operating parameters into the processor at any time, thus incorporating the "stand-by table" parameters into the operating program. Processing will then continue in the new operating mode.

Included as part of the 60-db processor is a precision simulated coherent video target generator which is used to check and calibrate the operation of the signal processor. Under manual control of the operator it will generate a target whose pulse width and shape, doppler frequency, range position, and amplitude are all independently variable. Provision is made to add a second target at the same range but different doppler, and also to precisely control the signal-to-noise ratio of the output.

Figures 5, 6 and 7 are photographs of three display formats using the target simulator as the system input. Figure 5 is a typical doppler/range display showing a target at 7-Hz doppler with a level of -20 db. Figure 6 shows a doppler/time format with time increasing from left to right. This is a track that would be generated by a target travelling at a constant velocity (12-Hz doppler) followed by a period of linear acceleration, followed by another period of constant velocity (20-Hz doppler). The total time history represented here is 3-2/3 minutes. The PRF for these two examples was 90 pps, giving a doppler extent of 45 Hz.

Figure 7 demonstrates the dynamic range of the equipment. It is a display of amplitude versus doppler and shows a full scale target (zero db) at 7-Hz doppler and a -60 db target at 9 Hz. The doppler extent was 30 Hz (60 PRF). It will be noted that all spurious signals and noise components are well below the -60 db target in amplitude. In the preceding examples the analysis was performed with a doppler filter of 0.15-Hz bandwidth. The analysis channel was operated in the linear analysis mode, using $\cos^2$ time-amplitude weighting to reduce doppler sidelobes.

Late in the development process the Naval Research Laboratory had the good fortune of obtaining from the Rome Air Development Center a Sylvania-built digital canceller. The canceller is a greatly improved digital equivalent of the two-stage delay line canceller used in the original MADRE equipment. It is the digital implementation of two stages of 5-pole filters and appears to be capable of clutter rejection of the order of the presently used crystal comb filters. Modifications are being retrofitted to both the 60-db processor and the canceller and they will be integrated soon after the processor arrives at the Chesapeake Bay Division of the Naval Research Laboratory. Thus the flexibility of the OTH radar will be further enlarged to the extent that it will be able to operate on any PRF from 7.5 pps to 360 pps.

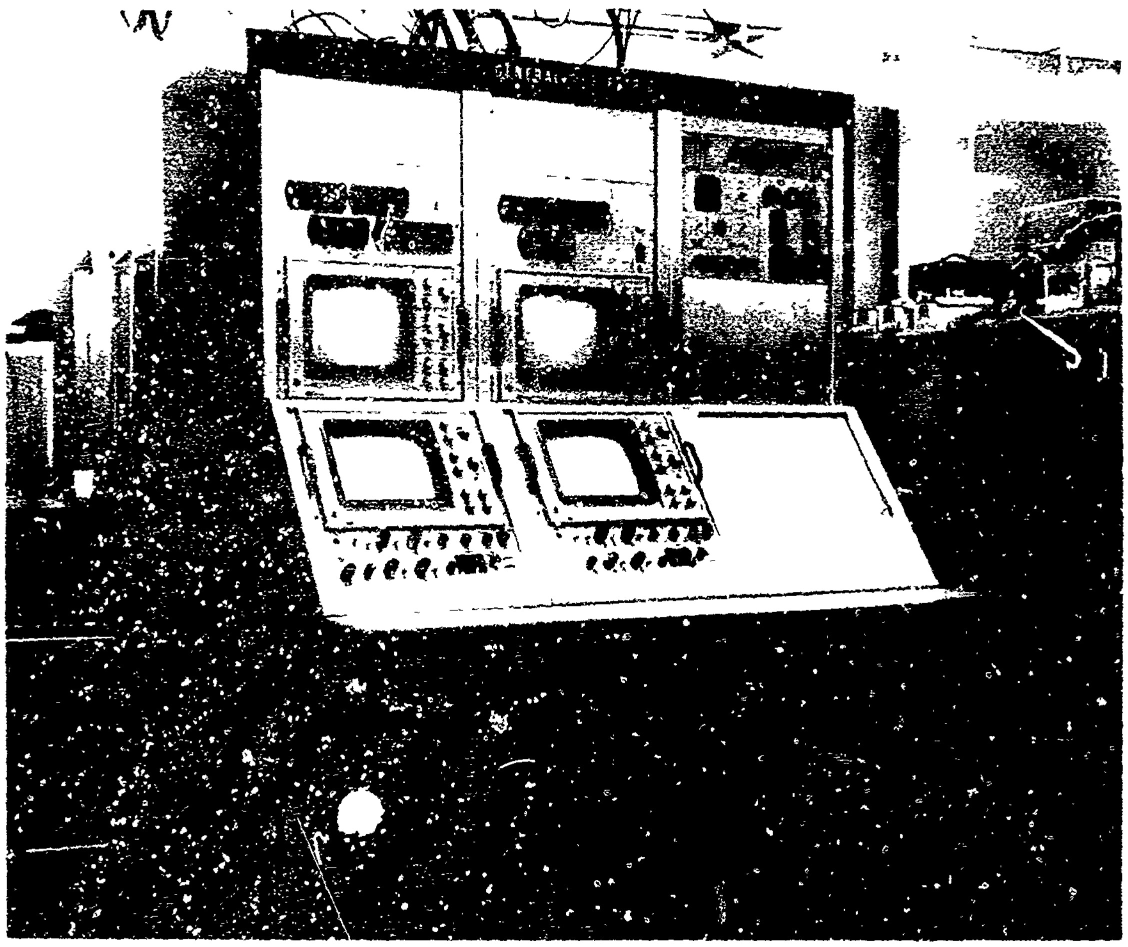

Fig. 1 -- Display and control console

Fig. 2 - Electronic racks. Input and timing circuits are in the two foreground racks. Memory and memory control circuits are in the three middle racks. The analog analysis circuits are in the two racks in the background.

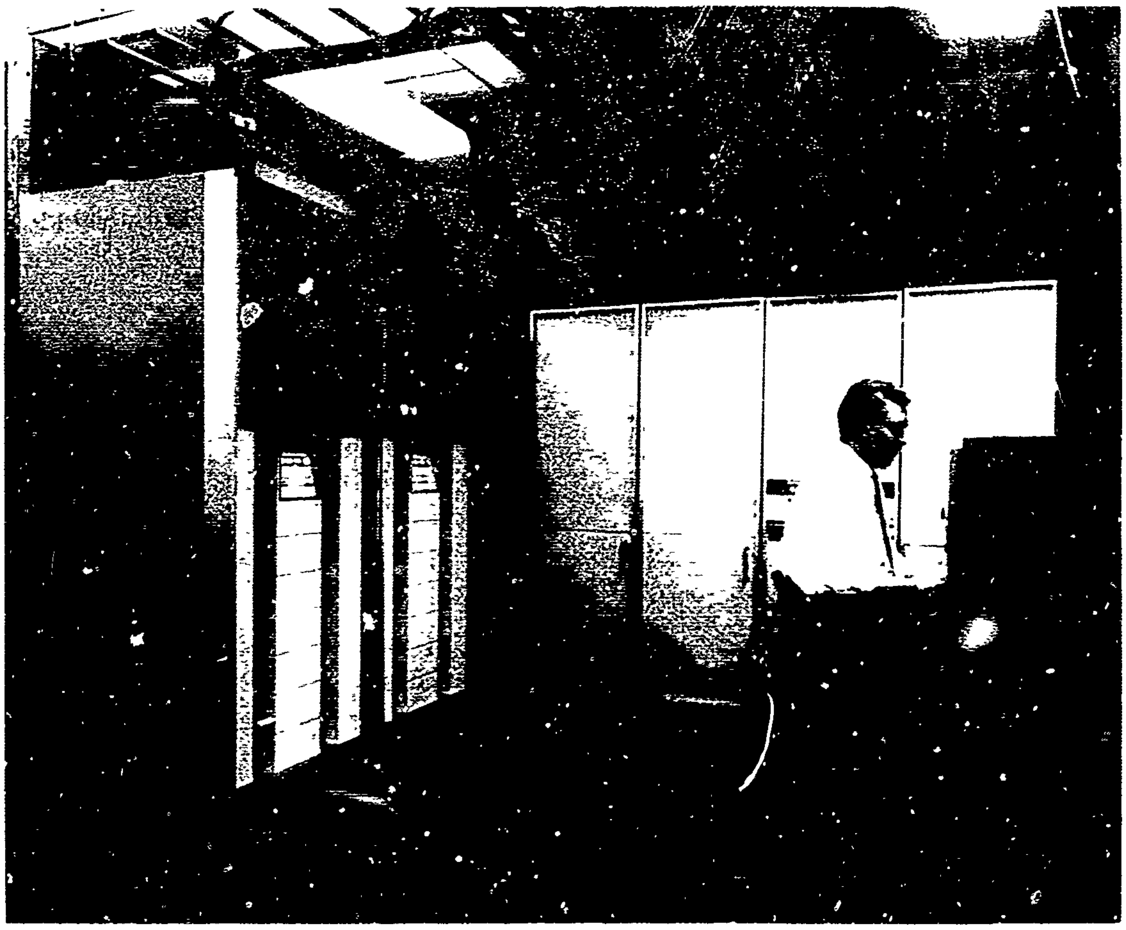

Fig. 3 - Computer. This view shows the computer that serves as the process controller. The two tape machines are used for permanent record of the input radar data.

Table 1
Selected system specifications

SYSTEM SPECIFICATIONS

PROCESSING MODE	--	REAL TIME OR TAPE PLAYBACK
PRF (BASIC)	--	11.25, 22.5, 45, 60, 90, 120, 180 pps
SAMPLE RATE	--	4 kHz OR 8 kHz PER CHANNEL, UP TO 50 kHz TOTAL
ENCODING ACCURACY	--	12 BITS
INPUT BANDWIDTH	--	100 kHz AMPLIFIER BANDWIDTH, 750 Hz OR 1500 Hz FILTER
APPROACH/RECEDE GATES	--	4 kHz OR 8 kHz RATE, POSITIONABLE ANYWHERE IN RANGE
INPUT CHANNELS	--	2 OR 4 DATA CHANNELS, BACK-SCATTER, VOICE
EXTERNAL CLOCK	--	SELECTION PERMITS ANY PRF FROM 7.5 pps TO 360 pps
PROCESSING GAIN	--	UP TO 30 dB
DYNAMIC RANGE	--	60 dB MINIMUM

Table 2
Selected storage and analysis specifications

STORAGE AND ANALYSIS SPECIFICATIONS

STORAGE MODE	--	DOPPLER RANGE OR DOPPLER TIME
NO. OF MEMORY SECTIONS	--	1, 2, OR 4 PER MEMORY, INDEPENDENT
RANGE EXTENT	--	UP TO 1800 nmi
LOCKUP	--	ANY MEMORY SECTION
MEMORY READOUT	--	FULL READOUT OR EITHER HALF OF EITHER MEMORY
STORAGE TIME	--	0.625 SEC TO 10 SEC IN DR; 110 SEC TO 880 SEC IN DT
DOPPLER RESOLUTION	--	0.15 Hz to 2.4 Hz
ANALYSIS MODE	--	FULL $\frac{PRF}{2}$ OR ANY $\left[\frac{PRF}{10}\right]$ SECTOR
DISPLAY FORMATS	--	DOPPLER/RANGE, DOPPLER/TIME, AMPL./RANGE, AMPL./DOPPLER

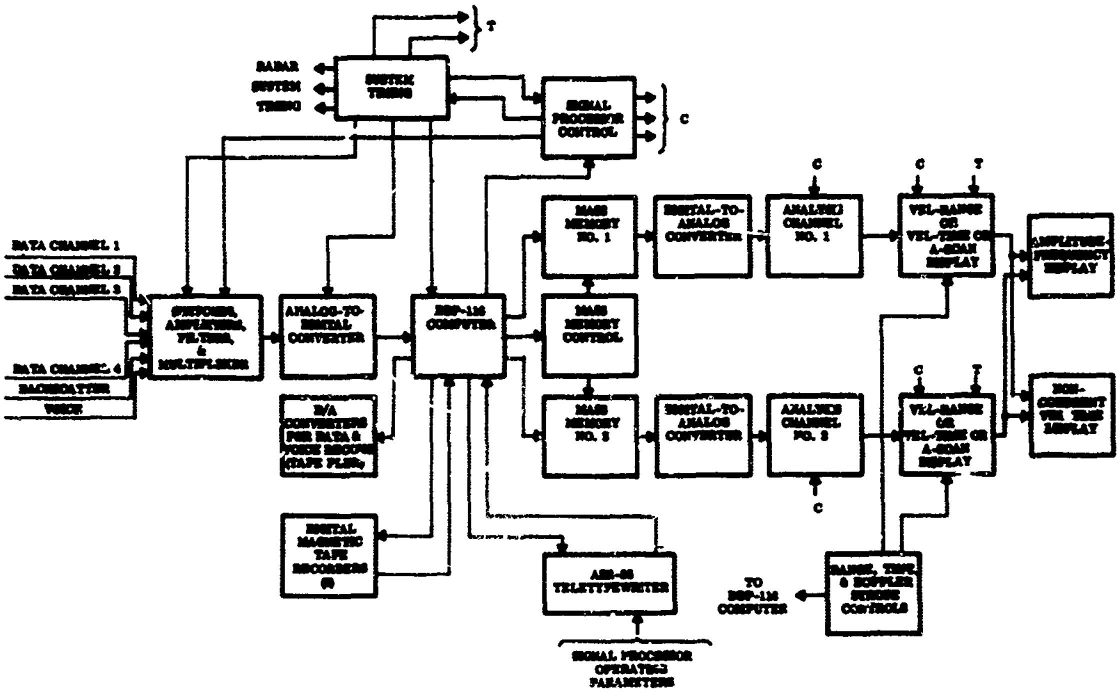

Fig. 4 - System block diagram

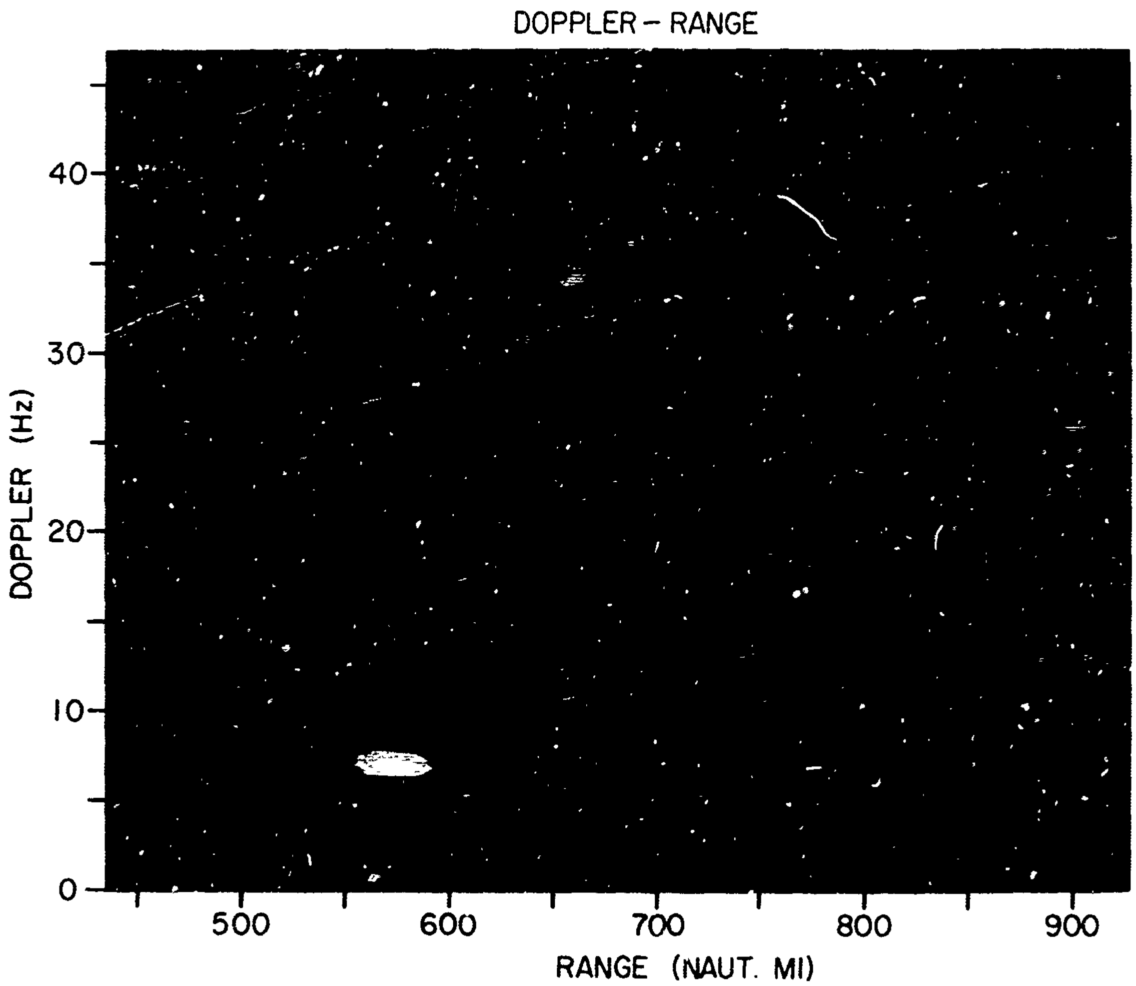

Fig. 5 - Doppler/range display. The target is a simulated signal of 7-Hz doppler frequency at a -20db level

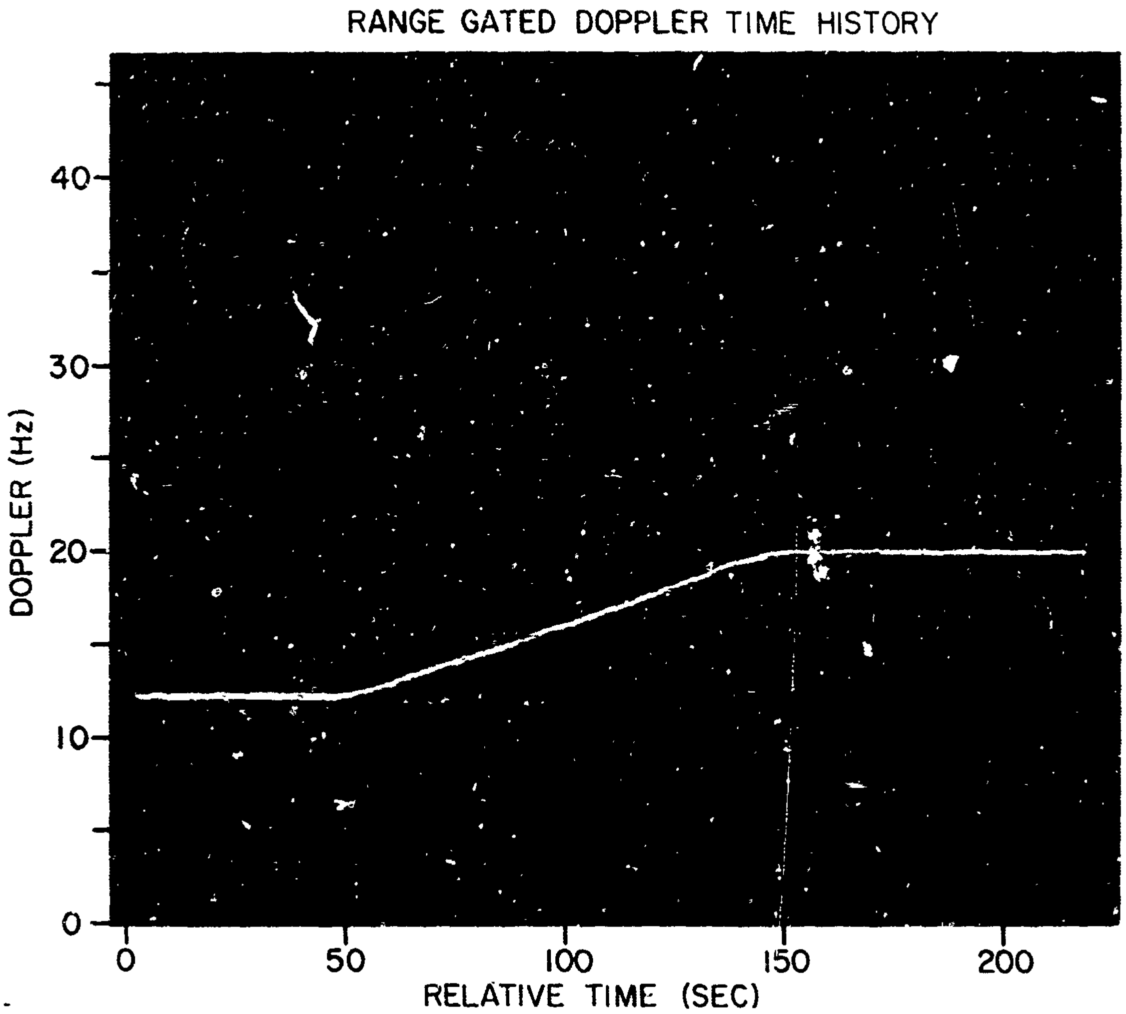

Fig. 6 - Doppler/time display. This is a simulated track of a target traveling at a constant velocity of 12-Hz doppler, followed by a period of linear acceleration, followed by another period of constant 20-Hz doppler.

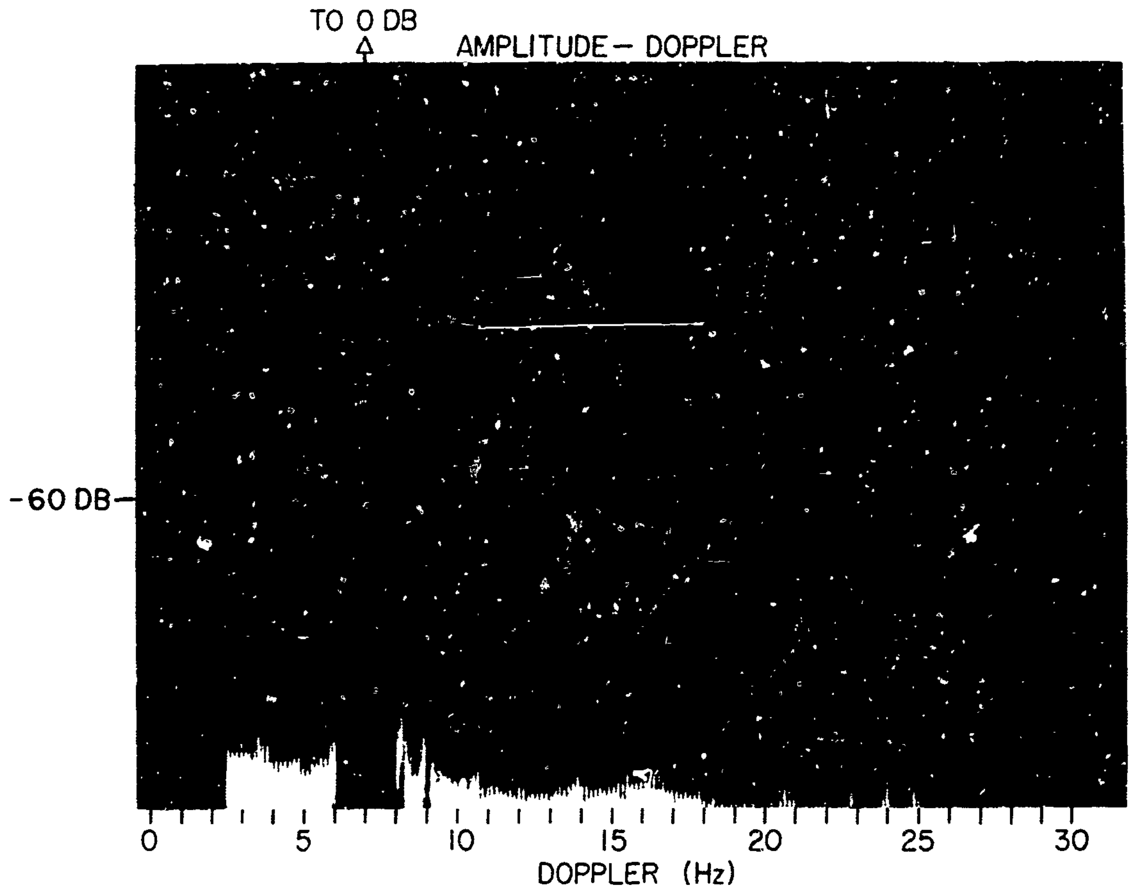

Fig. 7 - Amplitude/doppler. This shows a 7-Hz doppler signal at 0-db level. The second signal is a 9-Hz doppler at -60 db.

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Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Naval Research Laboratory Washington, D. C. 20390	2a. REPORT SECURITY CLASSIFICATION SECRET 2b. GROUP 3
3. REPORT TITLE A DIGITAL STORAGE WIDE DYNAMIC RANGE SIGNAL PROCESSOR (U)	
4. DESCRIPTIVE NOTES (Type of report and inclusive dates) Interim report on the problem	
5. AUTHOR(S) (First name, middle initial, last name) F. E. Wyman, B. Cameron, and B. L. Holtzclaw	
6. REPORT DATE	7a. TOTAL NO. OF PAGES 18 7b. NO. OF REFS
8a. CONTRACT OR GRANT NO. R02-42 b. PROJECT NO. USAF MIPR (30-602) 64-3412 c. ARPA Order No. 160, Amendment No. 7 d.	9a. ORIGINATOR'S REPORT NUMBER(S) NRL Memorandum Report 1787 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)
10. DISTRIBUTION STATEMENT In addition to security requirements which apply to this document and must be met, it may be further distributed by the holder only with specific prior approval of the Director, Naval Research Laboratory, Washington, D.C. 20390.	
11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY Air Force Advanced Research Projects Agency

13. ABSTRACT (Secret)

The Naval Research Laboratory is in the process of obtaining a new 60-db Dynamic Range Digital Processor for use with its over-the-horizon radar. It consists of the following subunits: (1) input control and general process controller, (2) digital core memory, (3) analog scanning filters and (4) dual display unit. It will operate at nominal PRF's of 180, 120, 90, 60, 45, 22-1/2 and 11-1/4 pulses per second with storage times of 10, 5, 2.5, 1.25 and 0.625 seconds in the doppler range mode and 110, 160, 220, 330, 440 and 880 seconds in the doppler time mode. An analog tape unit and a 12-bit digital tape unit which records up to four receiver channels are available at all times. These records can be analyzed with complete flexibility of analyzing parameters at a later time. The operational control of the processor is inserted in the process controller in the form of a magnetic or punch paper tape program and the general operational concept can be varied within wide limits by writing new programs. The day-to-day radar parameters and corresponding processor parameters are entered by use of typewriter control at the display unit. The displays will present data in both doppler-range and doppler-time formats and in addition will give amplitude versus range or time at manually selected doppler frequencies. A coherent video target simulator of high quality is included to provide a processor check and to aid in evaluation.

DD FORM 1 NOV 65 1473 (PAGE 1)

SECRET
Security Classification

S/N 0101-807-6801

14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Signal processor						
60-db dynamic range digital processor						
Over-the-horizon radar						

MEMORANDUM

20 February 1997

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Encl: (a) Code 5309 Memorandum of 29 Jan. 1997
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1. In Enclosure (a) it was recommended that the following reports be declassified, four reports have been added to the original list:

Formal: 5589, 5811, 5824, 5825, 5849, 5862, 5875, 5881, 5903, 5962, 6015, 6079, 6148, 6198, 6272, 6371, 6476, 6479, 6485, 6507, 6508, 6568, 6590, 6611, 6731, 6866, 7044, 7051, 7059, 7350, 7428, 7500, 7638, 7655. Add 7684, 7692.

Memo: 1251, 1287, 1316, 1422, [redacted], 1500, 1527, 1537, 1540, 1567, 1637, 1647, 1727, 1758, 1787, 1789, 1790, 1811, 1817, 1823, 1885, 1939, 1981, 2135, 2624, 2701, 2645, 2721, 2722, 2723, 2766. Add 2265, 2715.

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